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TRITIUM CONSOLIDATION COMPARISON STUDY: RISK ANALYSIS

December 1992

Prepared for:
U.S. Department of Energy
Assistant Secretary for Defense Programs
Office of Weapons Complex Reconfiguration

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DISCLAIMER

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Prepared by:
Harold Burton
Donald Chung
Roger Mattson
Vincent Panciera
SCIENTECH, Inc.
Rockville, MD 20852
Under Contract No. DE-AC01-92DP00248

Prepared for:
U.S. Department of Energy
Assistant Secretary for Defense Programs
Office of Weapons Complex Reconfiguration
Washington, DC 20585

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The Office of Weapons Complex Reconfiguration (DP-40) in Defense Programs of the Department of Energy requested that SCIENTECH, Inc. compare the radiological risk to the public from consolidating future activities involved with the maintenance, processing and storage of tritium for nuclear weapons at one site, either the Mound Plant in Miamisburg, Ohio or the Savannah River Site near Aiken, South Carolina. The relative risk between the two sites is one element of the decision of where to consolidate the activities. The Office also asked for a comparison of the risk at both sites to the safety goal of DOE, as described in Secretary of Energy Notice SEN 35-91.

The approach taken for this task was to conduct a critical review and extension of the analyses in the Facility Safety Analysis Reports (FSARs) for the sites. A team of three engineers visited the tritium facilities at the Savannah River Site and the Mound Plant for three days apiece. Each visit involved a number of activities to provide the team with an understanding of the tritium facilities; the design and operational capabilities of the tritium handling structures, systems and components; the accident scenarios and mechanisms that bear on risk; and the intended distribution of the consolidated tritium inventory at each facility.

In addition, the team reviewed plans for performing tritium handling, processing and storage activities after consolidation takes place. The team was briefed on the basic physical, chemical and radiological characteristics of tritium and the processes used to refine, mix, and load tritium into reservoirs. The team participated in guided walkdowns of the tritium handling, processing, and storage areas. These walkdowns included reviews of normal, and off-normal operations that could lead to accidents. Discussions of potential human errors, structural failures and equipment malfunctions were included in these reviews, together with a step-by-step discussion of accident scenarios that are within and beyond the design basis for the facilities. Included in these discussions were best estimates of probabilities for sequences that might occur in various accident progressions.

This team made quantitative comparisons of the consolidated tritium activities at Mound and SRS for four areas, namely, (1) transportation accidents, (2) expected releases during routine normal operations, (3) an operating basis accident (OBA) resulting from plant internal events within the design basis that could cause the release of tritium from process systems during operations, (4) accidents of very low probability that would be beyond the design basis of the facilities.

The central conclusions of this study are as follows: source terms and probabilities associated with transportation accidents are negligible compared to the other events evaluated. When probabilities are taken into account, population exposures from normal operations are higher than population exposures associated with accidents at both sites. Because of higher population density and a smaller site, for identical operational releases, Mound would have a higher population exposure by a factor of seven within 10 miles of the site boundary than does SRS. The exposure resulting from the selected operating basis accident (OBA), for the distances analyzed, were very low for both sites. The difference in risk between the two facilities for credible accidents (i.e., those within the design basis) is within the uncertainties of the calculations. Accidents beyond the design basis (e.g., a very large earthquake) present higher individual exposures and population exposures at Mound, primarily because SRS is a large site, away from densely populated areas.

It is also shown in the report that consolidation of tritium activities at either SRS or Mound would fall within DOE safety goals contained in SEN 35-91.

TRITIUM CONSOLIDATION

COMPARISON STUDY:

RISK ANALYSIS

SCIENTECH, Inc.
Rockville, Maryland

1.0 Purpose of the Report

The Office of Weapons Complex Reconfiguration (DP-40) in Defense Programs of the Department of Energy requested that SCIENTECH, Inc. compare the radiological risk to the public from consolidating future activities involved with the maintenance, processing, and storage of tritium for nuclear weapons at one site, either the Mound Plant in Miamisburg, Ohio or the Savannah River Site near Aiken, South Carolina. The relative risk between the two sites is one element of the decision of where to consolidate the activities. The Office also asked for a comparison of the risk at both sites to the safety goal of DOE, as described in Secretary of Energy Notice SEN 35-91. This comparison will assure that whichever site is chosen, it will not exceed the DOE safety goal.

SCIENTECH provided a preliminary comparison of the risks on August 12, 1992. That preliminary effort concluded that direct comparisons could not be made between the risks cited in the safety analysis reports for the two facilities, and that there were values used in the safety analysis reports that needed further justification before meaningful comparisons were possible. Also, it was concluded that the assumptions underlying the preliminary analysis were too simple to answer the basic question that had been posed. This report summarizes the additional analysis that was recommended at that time.

In an effort to compare the facilities on a common basis, a "level playing field" approach was devised. This approach defined 10 elements. These elements define standard input to the approach used to compare the risk at these facilities. These elements are as follows:

1. The total amount of tritium to be consolidated will be the same at either site.

2. War Reserve (WR) reservoirs will be assumed to have the same fragility at both sites. Tritium stored in non-WR containers will have the same fragility at both sites.

3. Realistic estimates will be used for the amount of tritium typically expected to be "in process" at the two sites, but the amounts typically used at the two sites need not be equal.

4. Comparable treatment will be accorded in risk estimates for the two sites as to the reliance that can be placed on structures, systems and components that are designed to the environmental and seismic conditions of the events they may be called upon to mitigate.

5. Realistic estimates of human reliability in conduct of operations will be used for both sites.

6. UCRL-15910 will be used for estimating the frequency and magnitude of natural phenomena and external events.

7. Population exposures will be calculated in the same manner for both sites, namely

   - identical exposure models will be used;
   - actual population densities will be averaged over annular sectors of identical size;
   - actual release heights will be used; and
   - calculations will be made for populations within 10 miles, and within 50 miles.

8. Exposures to maximum exposed individuals will be calculated in the same manner, namely

   - calculations will be requested from the M&O contractors for two representative standard problems involving individual exposure for Mound and SRS using their own exposure estimation models;
   - SCIENTECH will perform the standard problems to confirm its models; and
   - calculations will be made by SCIENTECH, using the confirmed models, for individuals at the site boundary (or location of plume contact).

9. All WR reservoirs will be assumed to be unloaded prior to end of life, and the tritium in them will be assumed to be placed in containers of comparable resilience to natural phenomena and other potential accident initiators.

10. Transportation will be assumed to pose the same risk per unit of tritium transported regardless of destination.

2.0 Background

2.1 Basic Information

Tritium is a radioactive isotope of the element hydrogen. Chemically, tritium acts like hydrogen in its propensity to combine with other elements to form chemical compounds. Like hydrogen, tritium oxidizes to form tritium oxide or tritiated water, which can include chemical combinations of hydrogen, deuterium, tritium and oxygen (i.e., TTO, TDO, THO). Tritium is radiologically unstable and decays by beta emission to produce Helium-3 and a beta particle with a maximum energy of 0.0185 MeV (average energy of 0.006 MeV). The half-life of tritium is 12.3 years. Tritium is a radiological hazard because of its beta emissions.

Tritiated water is about 25,000 times more hazardous to humans than the elemental form of tritium. The difference owes to the fact that tritiated water is retained by the body, allowing residence time for the beta emissions to damage cell tissues. Elemental tritium enters the body through the inhalation process, but not much is retained in the body. Elemental tritium in contact with skin also does not result in much absorption, and the beta radiation is not energetic enough to penetrate the skin. Tritiated water, however, is absorbed into the pores of the skin.

For health reasons, tritium is confined. There are usually several confinement barriers. The primary confinement consists of a barrier formed by system piping, tanks, other containers, and fittings. Bell jars are sometimes used as a backup, e.g., when the primary confinement boundaries have been penetrated for maintenance or other special conditions. The secondary confinement consists of an outside pipe wall in a double-walled piping design, glove boxes that surround the primary confinement, and a nitrogen-purging system with tritium-stripping equipment, which is connected to the glove box atmosphere. A tertiary system is used in some facilities to capture tritium released from the secondary confinement and reduce the tritium fraction in the air before releasing it to the atmosphere.

The tritium in nuclear weapons must be replenished periodically due to the decay of tritium and the buildup of helium. Tritium reservoirs are removed from nuclear weapons and replaced with reservoirs containing a fresh charge of tritium. The depleted reservoirs are returned to the processing site, where their tritium is removed and processed to remove helium. Fresh tritium is then placed in the reclaimed reservoirs for storage or use.

2.2 Description of Tritium Facilities at Savannah River Site

This section briefly describes the tritium facility at SRS, the site features, the major buildings that will be used if consolidation were to take place at SRS, including their capacity to accommodate various hazards, such as earthquakes and accidental releases of tritium.

The tritium facilities at the Savannah River Site are in the 200 H-Area which is near the center of the site. H-Area is at an elevation of 200 feet above the Savannah River. The Replacement Tritium Facility (RTF) will be the major tritium process building after consolidation. The nearest site boundary from the RTF stack is 7.3 miles in the northwest direction. A ten mile radial zone would include all SRS operational areas and the nearby towns of New Ellenton and Jackson. Key population centers that are included in a 50-mile radial zone are Augusta, Georgia; North Augusta, South Carolina; Orangeburg, South Carolina.; and Aiken, South Carolina.

The existing tritium operations are located in four buildings at SRS, namely, 232H, 234H 236H, and 238H. A fifth building, 233H called the RTF, is 99% complete and is intended to become operational within the next year after completion of testing and conduct of a DOE Operational Readiness Review. Many of the tritium operations currently performed in Buildings 232H and 234H will be transferred to Building 233H under the terms of a consolidation plan developed by Westinghouse Savannah River Corporation (WSRC), the M&O contractor for SRS. Buildings 236H and 238H will not process tritium after consolidation. Therefore, these buildings are not relevant to the subject of this report.

The RTF will be the principal building for tritium processing operations if consolidation were to be implemented at SRS. The RTF is an underground, reinforced concrete structure. The building is designed to be watertight and is designed to withstand a ground acceleration of a 0.2 g and tornado winds of 136 mph. The ventilation system is designed to maintain a continuous, once-through air flow pattern from the outside environment into areas not contaminated with tritium, then to potentially contaminated areas, then to normally contaminated areas and then up a fifty-foot stack. The building is kept at a negative pressure with respect to the outside atmosphere. According to the 200-Area safety analysis report, the building and most of the process operations would survive natural phenomena and external events within the design basis for a high hazard facility.

At RTF, DOE has raised questions and concerns regarding the geotechnical basis and seismic adequacy of the facility. DOE intends to document these issues in a Safety Evaluation Report (SER) of the SAR, which is scheduled to be issued prior to the commencement of the DOE ORR. A full evaluation of the seismic adequacy, with resolution of the geotechncial concerns, is not available at this time.

Building 232H began operation in the late 1950's. It is a T-shaped, one-story building of reinforced concrete with a full basement under the east-west wing (the top of the T). In the past, the basic mission of the building was to extract and enrich tritium from either solid target assemblies or from recycled reservoirs and deliver it in gaseous form to Building 234H. The structure of the building is blast resistant and of conventional industrial design. The building will survive a 0.2g earthquake according to its SAR.

Building 234H began operation in 1957. The basic mission of Building 234H has been to load and unload gas reservoirs. It also contains storage areas for tritium reservoirs. It is a one story building constructed of steel beams and columns, not reinforced concrete. The exterior walls are corrugated Transite sheathing on steel studs, and the interior walls are flat Transite board. The floors are concrete and the roof is metal. According to the SAR and interviews with the M&O contractor, Building 234H will survive earthquakes of 0.1g ground acceleration and other external events within the design basis for a moderate hazard facility. However, a 0.2g earthquake or a wind of 150 to 200 mph would cause gross failure of building structures.

2.3 Description of Tritium Facilities at Mound Plant

This section briefly describes the tritium facilities at Mound and the major building (T-Building) that will be used if consolidation were to take place there, including the capacity of T-Building to accommodate various hazards, such as earthquakes and accidental releases of tritium.

Mound Plant is located within the metropolitan area of Miamisburg, Ohio. The nearest site boundary from the T-Building stack is 300 meters (0.2 miles) away. A 0.5-mile radial zone would include all of Mound Plant and some residential areas and industrial parks in the city of Miamisburg. A ten mile radial zone would include all of Miamisburg and certain suburbs of Dayton, Ohio. Key population centers that are included in a 50-mile radial zone are Cincinnati and Dayton, Ohio.

The T-Building is one of the original buildings constructed at Mound, having been built in 1948 for a mission related to the production of polonium 210 and its fabrication into components for nuclear weapons. The T-Building is an underground, massive, reinforced concrete structure containing two functional floors. The exterior, reinforced concrete walls of the building are a minimum of 16 feet 7 inches thick. The 30 foot thick ceiling and 8 foot thick basemat also are constructed of reinforced concrete. The building was designed to survive a direct hit by a 2,000-lb semi-armor piercing, jet-assisted aerial bomb or a general purpose 2,000-lb contact bomb. The interior dimensions are approximately 151 ft wide, 345 ft long, and 30 ft high. Entrances to the building include two large doors in the south wall at each end of the upper operations floor that permit vehicles to enter the building. In addition to these two entrances, two towers along the north wall, one at the east end and one at the west end, contain stairways, passenger elevators, and air shafts. A third tower at the center of the north wall was originally built for incoming air, but currently is not used.

The T-Building is classified by EG&G, the M&O contractor, as a moderate hazard facility as defined in DOE Order 6430.1A. UCRL-15910 requires that a moderate hazard facility at this location be designed for 0.15 g design basis earthquake (DBE). If the facility were to be classified as a high hazard facility, a DBE of 0.23 g would be required.

According to the SAR for T-Building, the building and the process operations it contains are expected to survive all credible natural phenomena events (earthquakes, tornadoes, etc.) and external events (offsite explosions and aircraft crashes) within the design basis for a moderate hazard facility.

The T-Building probably was designed to the Uniform Building Code that was current at the time of construction, but no records remain to confirm this supposition. Also, there is no record of a ground acceleration value being incorporated in the design. In more recent times, the building has been shown by dynamic analysis to meet a ground acceleration of 0.2 g without significant structural damage. The SAR says that the dynamic analysis was done by the former M&O contractor, Monsanto, in 1974 using a limit analysis method, taking into consideration inelastic effects on frequency and structural response, basing failures on ultimate strength with no load factors, combining modal responses by the peak root mean square method, and using a derivative of the STRUDL code in use at the time in the commercial nuclear industry. The Mound SAR calls this 0.2 g value an "Extreme Earthquake" which provides "the reader an overall perspective of the integrity of the T-Building."

T-Building has been shown by its M&O contractor to be capable of withstanding a 360 mph tornado.

The team was told that new equipment and systems added to T-Building since 1978, have been designed to a DBE of 0.15 g. A company named Paul J. Ford, using an equivalent static load analysis, reportedly recommended various equipment anchorages that were incorporated into the construction of Kyle facilities in 1984. No one could recall for the team what the g-value was for that study or provide a report to document the study.

The team was told that it is EG&G's intention to seismically design all new systems and equipment associated with tritium consolidation at Mound to meet a DBE of 0.15 g, e.g., the new TERF facility described in Section 3 of this report. Equipment that is currently in place is to be seismically analyzed, and case-by-case decisions are to be made on backfitting the equipment to meet a 0.15 g DBE.

Construction was completed in 1985 on a major renovation of T-Building. The modification included installation of the Kyle and the Savannah River Operations Contingency (SROC) production facilities. The renovation provided a capacity to assemble, reclaim, and load reservoirs. Triple confinement concepts developed and proved feasible at Mound prior to 1980 were incorporated into the design of the Kyle and SROC facilities and subsequent modification projects, where applicable. That is, the design provides for 3 barriers between tritium and the environment.

The Semi Works (SW) Building and the west side of the Research (R) Building make up the remainder of the current Tritium Complex at Mound. This SW/R Complex, which has about 42,000 square feet of floor space, consists of four major operations: Process Development, Component Evaluation Operations (CEO), Tritium Recovery, and Materials Analysis. The SW/R area also houses the Effluent Removal System, which captures tritium effluents from process operations within the glove boxes in SW/R and T-Building. Materials Analysis in SW/R provides analytical and metallurgical support for all the tritium operations in the SW/R Complex. EG&G proposes to move CEO, process development, life storage development, tritium purification and material development, burst test/BP purification, and recovery into T-Building as part of its consolidation plan.

3.0 Proposals for Tritium Consolidation at the Two Sites

3.1 Tritium Operations After Consolidation

The consolidation of tritium activities at either SRS or Mound will require the performance of certain common functions. Common functions which will have to be done regardless of the location of consolidated activities, are as follows:

- Reservoir Unloading - Reservoirs returned from the war reserve program are unloaded (that is, the tritium gas is removed from them).

- Tritium Recovery - Product gas received from the unloading operations is processed to remove hydrogen and other impurities. The product gas is then transferred to storage beds to await isotope separation into pure tritium and deuterium gas streams, direct transfer to a mix tank for use as a blending material, or immediate loading.

- Isotopic Separation - Product gas is transferred to feed beds for isotope separation. The material is processed to produce tritium- and deuterium-enriched components. The isotopes removed from the process are stored separately on storage beds for use in mixing.

- Gas Mixing - Tritium and deuterium isotopes, or mixtures of the two isotopes, are blended in storage tanks. Isotope quantities are controlled to make the appropriate mixture. Mass spectrometer analysis verifies that the tank contents meet loading requirements. The storage or mix tank is then valved to a series of mechanical compressors that provide the loading pressure for reservoirs installed in a loading room.

- Reservoir Loading - Reservoirs are installed in independent positions connected by manifolds within a glove box to form what is called a loading room. Each loading position is verified to be leak-tight by a process of pressurization and evacuation. Target pressure is calculated, and the reservoirs are loaded to target pressure. Particularly close attention is paid to assure that the fill stems of WR reservoirs are completely and safely closed by welding.

- Reservoir Finishing and Packaging - The reservoirs are then finished and readied for packaging and shipment.

All of these functions except finishing and packaging are confined within a secondary confinement system to prevent the accidental release of tritium to the room, and thereby to the environment. The secondary confinement system consists of glove boxes with a nitrogen atmosphere which contain the process equipment. The secondary system is also equipped with stripper systems which remove any tritium released into the glove boxes through the primary confinement barrier.

Because the RTF systems have been designed to handle relatively large volumes of tritium for supporting previous stockpile demands, operation of these systems will require a larger in-residence inventory than is contemplated for Mound. Mound can be designed for processing the smaller stockpile demands currently contemplated.

3.2 Consolidated Tritium Facilities at SRS

Before discussing the unique features of the SRS consolidated tritium facilities that are relevant to this risk analysis, a short discussion of the WSRC plans for consolidation at SRS is presented

3.2.1 Proposed Consolidation at SRS

WSRC proposes to transfer many tritium-related activities that are presently conducted in Buildings 232H and 234H to the RTF when RTF becomes operational. At RTF, tritium would be unloaded from returned reservoirs, purified and enriched, and loaded into new or reclaimed reservoirs. That is, the RTF will replace the loading and unloading operations currently performed in part of Building 234H.

WSRC plans the following consolidation measures:

- Locate all tritium gas processing and handling, loading and unloading, and R&D operations in RTF;

- Leave existing operations of the Material Test Facility, cryogenic distillation and process stripper in Building 232H. Limit inventory of tritium to less than 10 grams in the cryogenic still and the process stripper;

- Locate the Mound Reservoir Environmental Chamber activities to the south truck port of Building 232H (WSRC plans to enclose this truck port to accommodate this installation);

- Locate the remaining consolidation missions, including Component Evaluation Operation, Gas Transfer, and Commercial Sales along with R&D in available space in RTF; and

- Maintain the Extraction Facility in building 232H in ready standby status for future operation as required to support SRS reactor operations.

Table 3.1 shows the estimated percentage distribution of the total tritium inventory after consolidation at SRS. Note that less than 16% of the total inventory will be located in RTF. The major portion of the consolidated inventory (about 84%) will be in reservoirs in Building 234H in the finishing, storage and packaging areas.

For this study, we have disregarded the production and extraction processes, assuming only that wherever extraction occurs, there will be need for a facility to place the tritium in adequately safe containers for transport to the consolidated processing facility.

3.2.2 Unique Features of SRS Consolidated Facility

The tritium facility at SRS, the RTF, is a new facility designed for tritium operations on the basis of 35 years experience in processing tritium for weapons applications. The facility was designed for processing (loading and unloading reservoirs and purifying tritium) the relatively large quantities of tritium required prior to the end of the cold war.

The RTF contains a central control room from which many of the operations and system lineups can be accomplished remotely. Tritium processing is accomplished using batch processes where the flow of process fluid is controlled from the central control room. In addition, many operational activities are automatically controlled by a computer. There will remain after consolidation certain activities that will require local manual operations, e.g., component evaluation operations and gas transfer systems.

The largest components in the processing operation at RTF are of the order of 1,500 liters, and about 9% of the total inventory is typically involved in reservoir loading and unloading at any particular time.

The double confinement used in RTF consists of: a) primary confinement which contains tritium within piping, valves, bottles, storage tanks, storage beds, and fittings of the system; and b) secondary confinement which consists of the outside pipe in a double-walled pipe design, glove boxes that contain the tritium process systems and the stripper systems that circulate nitrogen and tritium released to secondary confinement.

The glove boxes in RTF are maintained slightly below atmospheric pressure to prevent leakage to the room. To maintain safe operational pressure, small amounts of nitrogen must be discharged to the atmosphere. Nitrogen discharged from the primary stripper system is also pumped through the purge stripper and exhausted to the environment. Releases of tritium from secondary confinement (glove box or outer wall of double-walled pipe) to the room atmosphere during an accident are exhausted directly up the stack.

Four stripper systems (two primary, one secondary, and one purge system) utilizing zeolite beds (Z-beds) provide for recovery and confinement of tritium that leaks from primary confinement (reservoirs, tanks, beds, etc.). Nitrogen from the glove boxes cycles to and from one of two primary stripper systems to remove any tritium that might leak from primary confinement. A secondary stripper is available should any glove box accumulate a significant tritium concentration from leaks or maintenance work. A purge stripper removes tritium from nitrogen that needs to be discharged to the environment to maintain safe glove box pressure. The primary stripper system includes some redundant components to ensure continuous stripping capability, but the system is not safety grade and redundant power supplies have not been provided.

Each stripper system consists of a reactor, a pumping system, and Z-beds, while the recovery system consists of uranium beds, a pumping system, and tanks. As nitrogen from glove boxes passes through the reactor, hydrogen isotopes are oxidized to water vapor which is absorbed on the Z-bed. Before the zeolite is saturated with water, the Z-bed is removed from service. Beds are regenerated by removing them from service and heating them to drive off the water vapor. A recirculation loop carries the water vapor to the recovery uranium bed where it is reduced to the isotopic forms of elemental hydrogen. Hydrogen and its isotopes are stored in tanks for later processing by isotopic separation to recover the tritium and release the hydrogen to the environment.

The glove boxes in RTF are large, and there are regions inside the boxes that cannot be reached through the gloves. Thus, relatively less routine maintenance can be performed through the gloves. At RTF, the glass faces of glove boxes must be removed relatively more often to accomplish maintenance operations, since the equipment is not as readily serviced through glove ports. At RTF, tents cannot be constructed around glove box openings due to the small capacity of the secondary stripper system. Thus, at RTF, any accidental releases from the primary system during maintenance with a glove box face removed would be exhausted first into the room and then directly up the stack.

The buildings associated with tritium at SRS are equipped with fire detection and sprinkler systems. A walkthrough of the buildings did not reveal any excessive accumulation of combustibles even though RTF was still in a construction stage.

Tritium Operation	% Inventory (Upper Limit)	Location After Consolidation	Number of Boundaries
Component Evaluation	<1	233H/RTF	2
Gas Transfer Operation	<1	233H/RTF	2
Commercial Sales	<1	233H/RTF	2
Process Development	<1	233H/RTF	2
Life Storage Development	2	232H	1 or 2
Tritium Recovery	3	233H/RTF	2
Isotopic Separation	<1	232H	1
Process Stripping	<1	232H	1
Material Testing	2	232H	1 or 2
Reservoir Proof Testing	0	234H	NA
Mixing/Reservoir Loading	7	233H/RTF	2
Reservoir Finishing	3	234H	1
Reservoir Storage	79	234H	1
Reservoir Packaging	2	234H	1
Reservoir Unloading	2	233H/RTF	2
Reservoir Reclamation	<1	238H	NA
Burst Test/BP Purification	<1	236H	1

Table 3.1 WSRC Estimate of Percentage Distribution of Tritium Inventory after Consolidation at SRS

3.3 Consolidated Tritium Facility at Mound

Before discussing the unique features of the Mound consolidated tritium facility that are relevant to this risk analysis, a short discussion of the EG&G plans for consolidation at Mound will be presented.

3.3.1 Proposed Consolidation at Mound

At Mound, the tritium processing operations would be located in T-Building. At present, T-Building activities that relate to tritium handling, processing and storage are as follows:

- reservoir storage;
- isotopic separation;
- reservoir proof testing;
- mixing/reservoir loading;
- reservoir finishing;
- reservoir packaging;
- inert loading;
- reservoir reclamation;
- aqueous recovery;
- reservoir unloading;
- TERF and ECS; and
- gas transfer operation.

EG&G proposes to relocate the following activities presently conducted in the SW/R Complex to T-Building. These activities are:

- component evaluation;
- process development;
- life storage development; and
- tritium recovery

In a feasibility study report dated August 6, 1992, EG&G proposed facility upgrades to support consolidation. The most significant of these upgrades from a tritium risk perspective are:

- Reservoir Inspection and Storage - increased storage capacity will be added to handle gas reservoirs returned from the field. These WR reservoirs will be stored in T-Building using double confinement methods. In-process storage for the reservoirs will be conducted in triple confinement systems in T-Building.

- Reservoir Unloading - three unloading stations with multiple-position laser stations will be added.

- Tritium Recovery - increased capacity will be added to existing capability for tritium recovery.

- Isotopic Separation - additional capacity in refrigeration equipment and product storage equipment will be added. Additional storage capacity will be provided for the various gas mixtures required for the enduring stockpile. Presently, the separation facility contains 2 storage tanks, each with a capacity of 200 liters. In addition, there are smaller feed tanks containing volumes of 100 to 200 liters. It is planned to install another 300 liter tank. A uranium bed with a capacity of 100 grams also supports the separation process.

- Gas Mixing - additional capacity will be provided to meet the gas mixing requirements (number of types of gas mixtures) for the projected stockpile based on the single work shift requirements assumed for the consolidation study. It is planned to add 10 tanks, each with a capacity of 100 liters. Presently, one tank is available with a capacity of 250 liters. The gas in these tanks will be limited to a pressure of 3 atmospheres.

- Reservoir Loading and Finishing Operations - additional pinch welding stations will be installed to serve as backup to the current 10 pinch weld stations and to handle additional capacity for special reservoir designs. Some of the additional welding stations will be installed in different glove boxes from the current stations to ensure full-time redundant loading facilities that can be used during maintenance and other functions.

Table 3.2 shows the percentage distribution of the consolidated tritium inventory that would be typical for the Mound Plant. Approximately 99% of the tritium inventory, including all reservoirs, would reside in T-Building. In addition, WR reservoirs that are nearing the end of life and any non-WR reservoirs that are potentially more hazardous, will be stored within a secondary confinement, such as a glove box, within a room served by the tertiary confinement system and Emergency Containment System (ECS).

3.3.2 Unique Features of the Mound Consolidated Facility

The tritium facility at Mound is in an existing laboratory facility which has processed relatively small quantities of tritium in the past. The original intent of the SROC modification in the T-Building was to provide backup for the SRS tritium facility. This facility has undergone renovation and modification over the years and would need to be upgraded to handle the level of tritium processing expected in the future.

At Mound, the T-Building does not contain a central control room. Instead, operations and system line-ups in T-Building are conducted locally by the equipment operators. Also, process operations are not planned to be automated.

Mound uses smaller components in its process systems and has a lower throughput because the systems were primarily designed to accommodate laboratory quantities of tritium and to provide a backup to SRS. The largest components are of the order of 200 liters, and only about 5% of the consolidated tritium inventory is tied up in loading and unloading.

The triple confinement system used in T-Building consists of: a) primary confinement, which confines the tritium within piping, valves, bottles, storage tanks, storage beds, and fittings of the system or within bell jars during unloading operations; b) secondary confinement, which consists of the outside pipe in a double-walled pipe design, glove boxes that contain the tritium process systems, and the Effluent Removal System (ERS) which circulates nitrogen gas from the glove boxes through strippers that remove tritium that has leaked from the primary confinement; and c) a tertiary confinement, which comprises the room that contains the glove boxes and interconnecting double-walled pipes, and the ECS.

Tritium Operation	% Inventory (Upper Limit)	Location After Consolidation	Number of Boundaries
Component Evaluation	1	T-Building	1 or 2
Gas Transfer Operation	<1	T-Building	2
Commercial Sales	<1	T-Building	1
Process Development	<1	T-Building	1
Life Storage Development	2	T-Building	1
Tritium Recovery	1	T-Building	3
Isotopic Separation	1-2	T-Building	3
ERS -TERF	<1	T-Building/SW	2
Material Testing	<1	T-Building/SW	1
Reservoir Proof Testing	0	T-Building	NA
Reservoir Loading	3	T-Building	3
Reservoir Finishing	5	T-Building	2
Reservoir Storage	85	T-Building	2
Reservoir Packaging	5	T-Building	2
Reservoir Unloading	2	T-Building	3
Reservoir Reclamation	<1	T-Building	1
Burst Test/BP Purification	<1	SW	1
Solid Recovery	<1	SW	1
Aqueous Recovery	<1	T-Building	1

Table 3.2 EG&G Estimate of Percentage Distribution of Tritium Inventory after Consolidation at Mound

The tertiary confinement in T-Building is designed so that in accidents other than fires, air exhausted from the rooms containing significant quantities of tritium can be diverted through the ECS before release through the 200-ft stack. In the case of a fire, ECS will be bypassed when smoke is detected and the products of combustion, including tritium oxide, will be released directly up the 200-ft stack to the environment.

Under the current configuration, upon actuation of ECS following the detection of a tritium leak from secondary confinement to a room, ventilation system butterfly valves actuate to isolate the room and divert the exhausted air flow to the ECS. The ECS removes most of the tritium and recirculates 90% of the air flow back to the room. EG&G proposes to modify this system for single pass operation. This single pass system will limit the tritium oxide in the room in the event of an accident, while reducing the total curies of tritium released to the stack. If a release to a room were to occur, approximately 8% of the tritium release could escape through doors used for personnel egress following the release. This 8% would be gathered up by the ventilation system and released through the stack.

EG&G estimates that approximately 99% of the tritium entering the ECS will be captured by the ECS. The remaining 1% in the form of tritium oxide will be released to the environment through the stack. There is no backup to the ECS. If it fails to operate on demand, its admission valves fail closed so that the room with tritium is isolated until ECS is restarted.

The ERS located in the SW Building is a continuously operating system that removes and collects tritium and tritiated compounds from the effluent streams of tritium handling equipment for the SW/R Complex and T-Building. The effluent streams are exhausted through the ERS, where they are filtered to remove any particulates and liquid droplets before being cooled to remove any condensable vapor, particularly tritiated water. The remaining effluent is exposed to a heated catalyst to oxidize the tritium gas or any other tritiated organics that are still present. The oxidized tritium is collected and further purified for reuse. The ERS receives about 500,000 Ci per year and recovers all but about 500 Ci.

Work is nearing completion on a Tritium Effluent Removal Facility (TERF). It is located in T-Building and provides improved tritium removal capacity for the secondary confinement. With the present design, gaseous process effluents from all of Mound's tritium handling systems are collected in a series of headers and piped to a central processing system, the ERS. These gases will be shared with the TERF when it becomes operational. TERF will eventually replace ERS after a transition period of operation. In the TERF, the gases are filtered, compressed, heated, and passed through reactors where the tritium and tritium-containing compounds are oxidized to form tritiated water. After cooling, the tritiated water is removed from the gas stream as the gases are passed through molecular sieve drying towers. The decontaminated gases are then monitored and released to the stack. The total tritium feed to the system in a year's time is expected to be approximately 400,000 to 1,000,000 curies (40 to 100 grams of tritium).

Generally, the glove boxes are relatively small in T-Building, and people working through the gloves on either side of the boxes can reach one another's hands, i.e., there are few, if any, components inside the boxes that are out of reach of the gloves. Thus, routine maintenance can be performed through the gloves at Mound. When a glove box face is removed for maintenance in T-Building, a tent is constructed over the work space and the air flow through the tent into secondary confinement is passed through the ERS or TERF, before exhausting it to the environment.

The T-Building is equipped with fire detection and sprinkler systems. A walkthrough of the building by the Team did not reveal any excessive accumulation of combustibles.

4.0 Comparisons Between Mound and SRS

This section presents comparisons of radiological exposures to the public for consolidated tritium activities at Mound and SRS. The potential radiological exposures and associated probabilities are addressed in four areas, namely: (1) transportation of current tritium inventories between the two facilities to effect consolidation; (2) normal operations; (3) accidents within the design basis of the facilities; and (4) accidents beyond the design basis of the facilities. For each area, an estimate is developed for the amount of tritium that could be released, called the "source term." An evaluation of maximum individual exposure and population exposure is developed for each source term of significance. Since these exposures take into account the probabilities of the events leading to a release of tritium, they can serve as the basis for comparison of the consolidated operations.

4.1 Transportation

Source Term for Transportation Accident

Consolidation of tritium activities at one site would require shipment of existing tritium inventory from one facility to the other. The probability of an accidental release of tritium during such shipments is proportional to the quantity of tritium to be moved, i.e., the more shipments that are required, the higher the probability of an accident in transport. Since more tritium is currently at SRS, there is a difference in risk associated with the extra tritium that would have to be transported to Mound, other things being equal.

As a low energy beta emitter, tritium is shielded by stainless steel in its packaging. Radiation exposure to personnel involved in tritium-related transportation is negligible. The likelihood of an accident is proportional to the number of transport miles. In the many shipments of WR reservoirs and nuclear weapons that have occurred in the past, several aircraft accidents have occurred that led to the release of tritium from a reservoir. Based on aircraft accident rates for U.S. air carriers, the probability of an accident for a 600-mile flight is 1E-6 to 1E-7.

The size and probability of an accidental release of tritium can be calculated assuming the tritium will be transported in reservoirs by air, with each shipment containing the same number of reservoirs that is typical of current practice. The higher number of shipments associated with consolidation at Mound leads to a higher likelihood of transportation accidents associated with consolidation at Mound. In this analysis, it is assumed that during the consolidation process the tritium would be packaged and handled according to the existing DOT and DOE requirements, and any differences in packaging at Mound and SRS would not affect the risk calculation. There could also be some shipments of non-WR reservoirs, but about the same number of non-WR reservoir shipments would be required whether consolidation occurred at Mound or at SRS.

For each transportation accident, EG&G and WSRC agree that it is reasonable to assume that up to 50,000 Ci of tritium would be released in the elemental form. The probability of a major aircraft accident can be estimated on the basis of information in the "Mound Laboratory - External Event Analysis." The reservoir failure rate for an aircraft accident can be estimated on the basis of the rate of failures that have occurred in the past. This should be a conservative assumption, since new packaging will provide greater protection for future transportation activities. If there is a fire coupled with the accident, it is assumed here that the entire source term would be converted to the oxide form. Considering the high number of ignition sources during an aircraft accident, the probability that an accident will involve a fire is estimated to be 50 percent. Even in the event that the tritium is not converted to oxide through fire, one percent conversion is estimated to occur within a few hours in the vicinity of the release, as verified through experimental data.

There has only been one major transportation accident where tritium was released. Based on the number of failed reservoirs in the total shipment in that accident, the probability that a reservoir will fail in an air crash is estimated to be 1E-2.

The probabilistic release of tritium in a transportation accident is calculated below in Figure 4.1 for one shipment.

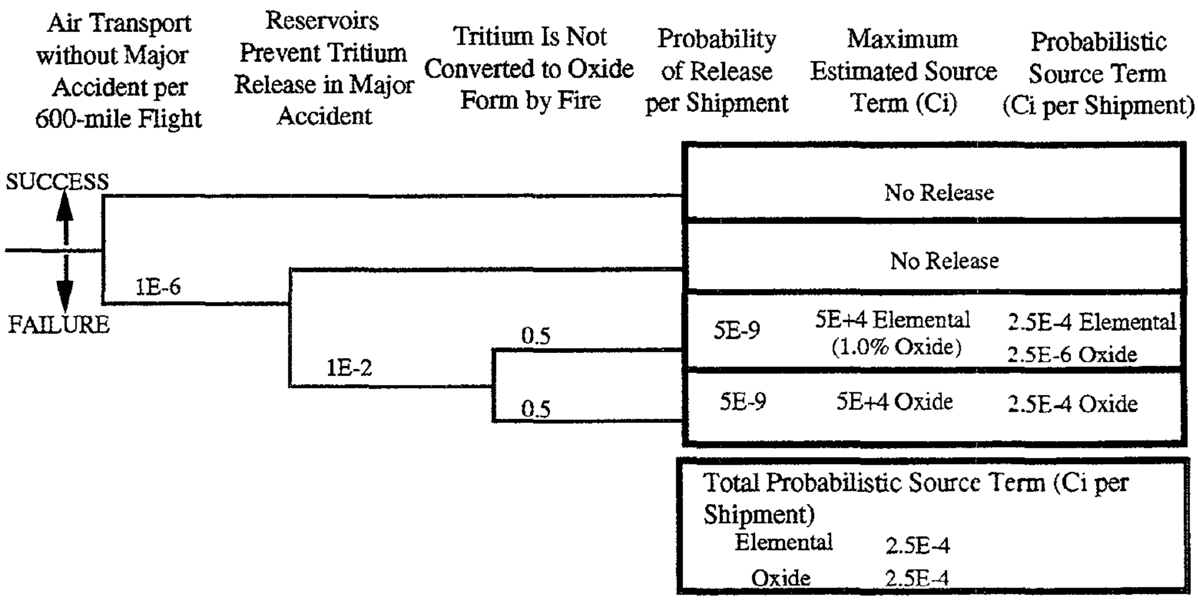

Figure 4.1 Typical Air Shipment of WR Reservoirs

The probability and source term are identified for each end state in this event tree. For the first two end states, no release is expected. For the third end state, elemental tritium is released; and for the fourth end state, a fire occurs and converts the entire release to the oxide form. The probabilistic source term is the product of the probability of an accident per shipment and the amount of tritium released in that accident. The total probabilistic source term is the sum of the individual products of probability and source term.

Exposures from Transportation Accident

The number of shipments is expected to be small. When consideration is given to the differential number of shipments involved with consolidation at Mound, compared to SRS, the total probabilistic source term is insignificant with respect to the other risks discussed below.

4.2 Normal Operations

Source Term for Normal Operations

The two facilities being evaluated have never operated in a production mode, therefore the estimates for operational releases after consolidation must be estimated. A great deal of operating history can be used as a basis for making such estimates.

According to the "Mound Tritium Feasibility Study," if an accidental release of 38,000 curies in 1989 is excluded, normal releases of tritium of the environment have averaged 3,500 curies/year from 1980 to 1991. EG&G estimates that reductions from this average are expected to be realized with a release range from 2,000 curies/year down to 1,000 curies/year. These are reasonable estimates for the source term for normal operations.

A recent presentation by WSRC to the DNFSB estimated tritium releases for normal operations at RTF would be about 2,200 curies/yr. This is a factor of 20 reduction over experience in existing facilities at SRS. This estimate is also reasonable for the future source term for normal operations which utilizes glove boxes rather than hoods.

There are differences in the facilities and equipment which mitigate the source terms from normal operations in the past. As low as reasonably achievable (ALARA) principles which will guide the operations are expected to result in considerable improvements, and in the long term, source terms as low as 50 curies/year might be achieved at both sites.

Population exposures have been estimated below for source terms of 2,000 curies/year and 50 curies/year associated with normal operations.

Exposures from Normal Operations

It is assumed, based on experience, that operational releases would be 70% tritium oxide, and the releases at each site would be at stack height. These assumptions are consistent with the Mound Site Environmental report for 1991 and SRS projections for RTF.

The build-up of the exposure rate from operational releases depends on the effective half-life of the radioisotope. For tritium, the effective biological half-life is approximately 12 days. For chronic exposure to tritium, the exposure rate reaches a plateau of a maximum exposure rate in less than 20 days. The team evaluated the maximum exposure rate for the normal operations source term using the National Council on Radiation Protection and Measurements (NCRP) model for chronic exposure. This approach takes into account the following pathways of exposure:

- tritium in drinking water,
- tritium in water in food,
- tritium oxidized to water upon metabolism of food, and
- tritium in atmospheric water.

The following assumptions are used:

- the normal operation release conditions are the same as those used for accident calculations (see Appendix A);
- the concentrations of tritium in air, drinking water, and food are the same;
- the atmospheric humidity is 6.6 and 8.4 grams of water per 1,000 liters of air at Mound and Savannah River, respectively; and
- the average individual water intake is 3 liters per day.

The maximum exposed individual (off-site) for the source term associated with normal operations at SRS is a person located at the nearest site boundary, approximately 7 miles from the release point. At Mound the maximum exposed individual is located 4 miles from the release point, where the center of the plume contacts the ground for the assumed meteorological conditions.

The resulting exposures are presented in Table 4.1 and are compared with exposures from natural background radiation.

	Individual Exposure From Background Radiation (rem/year)	2,000 curies/year Released as 70% Oxide (rem/year)	50 curies/year Released as 70% Oxide (rem/year)
SRS	3.1E-1	9.5E-3	2.4E-4
Mound	2.9E-1	8.7E-3	2.2E-4

Table 4.1 Maximum Exposed Individual (Off-Site) for Normal Operations Source Term

The resulting population exposures for Mound and SRS are shown in Table 4.2 and compared to background radiation levels.

	Population Exposure From Background Radiation (person-rem/year)	Exposure from Source Term of 2,000 curies/year Released as 70% Oxide (person-rem/year)	Exposure from Source Term of 50 curies/year Released as 70% Oxide (person-rem/year)
SRS (10 miles)	2.0E+4	2.2E+1	5.4E-1
Mound (10 miles)	9.4E+4	1.6E+2	4.0E 0
SRS (50 miles)	2.3E+5	8.7E+1	2.2E 0
Mound (50 miles)	8.8E+5	4.0E+2	1.0E+1

Table 4.2 Population Exposures for Persons within 10 and 50 Miles of the Site Boundary for Normal Operations Source Term

Note that the population exposures calculated here are about one thousand times or more lower than the population exposures from background radiation. These estimates of exposures associated with releases from normal operations are used in section 5.2 for risk comparisons with the DOE safety goal.

4.3 Accidents within the Design Basis

Accidents that are typically considered for safety analysis were examined to compare the differences between SRS and Mound for accidents within the design basis. For many of these accidents the probability of occurrence is less than 1E-6 per year, and the quantities of tritium that are susceptible to being released are relatively small. The accidents that were considered are listed in Appendix B.

Accidents associated with natural phenomena and operational events within the design basis were examined. The natural phenomena considered include: flood, earthquake, and severe wind and wind-generated missiles. The tritium facilities at SRS are 200 feet higher than the Savannah River, and Mound is over 100 feet above flood stage of the Miami River, therefore flooding is extremely unlikely at either site. Both SRS and Mound are considered moderate hazard facilities in accordance with the new DOE Guidance on the implementation of the DOE Order 5480.23. Based on the severity of moderate hazard earthquakes and winds given in UCRL-15910 for each site and the structural information in the FSARs for the two sites, there would be no significant failures resulting from earthquakes and winds within the design basis. Thus, there is no significant source term resulting from such events.

<u>Source Term Estimate for Operating Basis Accident</u>

The team selected an operating basis accident (OBA) to evaluate the probability and source term of accidents that could occur and release tritium. The OBA is representative of accidents within the design basis for the normal process operations at either Mound or SRS. The OBA selected was based on review of past operations and the current plans for consolidated tritium operation at Mound and SRS. The OBA was chosen to be a 10,000 curie release from a glove box within T-Building and RTF. Such a release is most likely to be caused by an operational or maintenance error.

The team considered differences in the following key characteristics of the two facilities in identifying the relative frequency of the OBA:

- mode of facility operation and maintenance,
- design of the glove box confinement system, and
- methods of confinement.

The physical design of secondary confinement for process systems is different between Mound's T-Building and the RTF at SRS. Generally, the glove boxes are smaller in T-Building, and people working through the gloves on either side of the boxes can reach one another's hands, i.e., there are few, if any, components inside the boxes that are out of reach of the gloves. The glove boxes in RTF are larger, and there are regions inside the boxes that cannot be reached through the gloves. Thus, more routine maintenance can be performed through the gloves at Mound. At RTF, the glass faces of glove boxes must be removed more often to accomplish maintenance operations, since the equipment is not as readily serviced through glove ports as at T-Building. Also, when a glove box face is removed for maintenance in T-Building, a tent is constructed over the work space and the air flow through the tent into secondary confinement is passed through the ERS or TERF, before exhausting it to the environment. At RTF, this mode of operation is not possible due to the smaller capacity of the secondary stripper system. Thus, at RTF, any accidental releases from the primary system during maintenance with a glove box face removed would be exhausted first into the room and then directly up the stack. These differences in glove box design and the capability of the secondary confinement cleanup systems result in a higher probability of releasing tritium during maintenance at SRS. Representatives of SRS and Mound have estimated that these differences in glove box design and cleanup system capability could result in a factor of 10 change in the probability of occurrence of a significant release to the room in RTF compared to T-Building.

At Mound, the T-Building does not contain a central control room of the type used in RTF and Building 232H at SRS. Instead, process operations and system line-ups in T-Building are conducted locally by the equipment operators. The inability to control process equipment remotely from a control room during off-normal or accident conditions results in a higher probability of release of tritium from a glove box at Mound. Also, some process operations have been automated at RTF to increase their reliability. Such automation reduces the likelihood of human error causing simultaneous loss of primary and secondary confinement during operations. The combination of remote control and automation at SRS is worth about a factor of 2 in decreased probability of an OBA in the judgment of the team.

The team estimates that these differences in glove box design and cleanup system capability, when taken into account with differences in automatic and remote control of some process operations at SRS, amount to a total factor of 5 higher probability for an OBA at RTF compared to an OBA at T-Building.

An elemental tritium release past primary and secondary confinement at RTF would exhaust from the building as essentially all elemental tritium. It would reach the environment via a 50-foot stack, then conversion to the oxide form would occur, over time, in the environment. The tertiary confinement in T-building at Mound is designed so that in accidents other than fires, air exhausted from rooms containing significant quantities of tritium can be diverted through the ECS where most of the tritium is captured and a small amount is released through the 200-foot stack in the oxide form.

The likelihood is very low that a fire or explosion internal to a tritium handling building will occur and thus lead to a release of tritium. In addition to formal control measures for combustible and explosive materials, each facility is equipped with fire detection and sprinkler systems, and two levels of physical separation (barriers) between a potential fire and tritium are provided by the primary and secondary confinement systems. The probability of fire causing a tritium release has been addressed at both Mound and SRS in the SARs and is estimated to be in the range of 1E-7 to 1E-6 per year. For this study 1E-6 per year is used.

If a tritium release is in the elemental form, some of it will convert to the oxide form before exposing people in the region of the release. It has been assumed in the analysis presented below that 1.0% will be converted to the oxide form. This assumption is based on data from experiments and accidents which indicate that the tritium-to-tritium oxide conversion rate will be about 1% or less in time spans of relevance to exposures occurring from accidental releases.

Based on the foregoing considerations, and after reviewing tritium releases that have occurred within glove boxes in the past, an OBA involving a release of 10,000 curies of elemental tritium through both primary and secondary confinements was chosen. The differences in the release characteristics for an OBA at RTF and at T-Building are illustrated in the two event trees in Figure 4.2 and Figure 4.3.

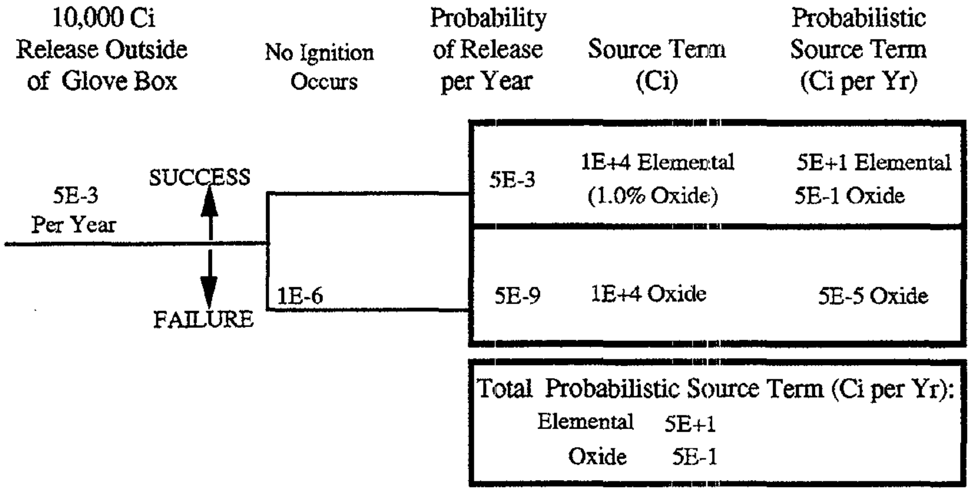

Figure 4.2 Operating Basis Accident at RTF

An OBA with a 10,000 curie release past the primary and secondary confinements at RTF is described in the above event tree. The first end state is estimated by the team to have a probability of occurrence of 5E-3 per year, and the source term is a release of 10,000 curies of elemental tritium through the stack. The probability of occurrence is based upon discussions with WSRC. This source term and probability of occurrence, when multiplied together, produce a probabilistic source term of 50 curies per year of elemental tritium of which 1% (5E-1 curies per year) is converted to oxide near the release.

The second end state is estimated by the team to have a probability of occurrence of 5E-9 per year. In this sequence, the source term is tritium oxide because a fire is postulated to occur along with the OBA. The probability of ignition of a fire used here is consistent with the FSARs for both facilities. The probability of occurrence and the source term when multiplied together produce a probabilistic source term for this accident sequence of about 5E-5 curies of tritium oxide per year.

The total probabilistic source term for tritium oxide, being the sum of the individual probabilities of source term for tritium oxide, is dominated by the 1% oxide in the source term for the first end state. To obtain the total oxide release in this event tree, the elemental tritium that converts to oxide in the first end state must be added to the oxide source term for the second end state, that is, (5E+1)*(E-2) + 5E-5 = 5E-1 of oxide.

In the case of Mound, an OBA that releases 10,000 curie of elemental tritium past primary and secondary confinement in T-Building, is estimated to have a probability of occurrence of 1E-3, for reasons described above. This probability of occurrence is also based upon discussions with EG&G Mound. Approximately 92% of any tritium that is released into a room served by ECS will find its way to ECS, and 8% would be exhausted to the hallways or other areas not served by ECS and be released to the environment via the 200-foot stack. Tests show that 99% of any tritium which enters the ECS remains there, while 1% is released as tritium oxide to the environment.

There has never been an accidental tritium release in the T-Building, and the tertiary confinement has never been challenged by an accidental tritium release. Tritium processing operations in the T-Building are divided into separate air-tight rooms. The tertiary confinement has the capability to confine an accidental release and to process the release through ECS. In the event of an accidental release, the room normal ventilation valves would be automatically closed and the air flow would be redirected to the ECS. If, however, these valves fail to close, the tritium would exhaust through the stack. A reasonable estimate of the probability of not having tertiary confinement as a result of failure of the valves to close is 2E-5. The event tree quantification of this accident, Figure 4.3, is not highly sensitive to this value. Even if the probability of not having tertiary confinement is two orders of magnitude higher (i.e., 2E-3), it would not affect the event tree results.

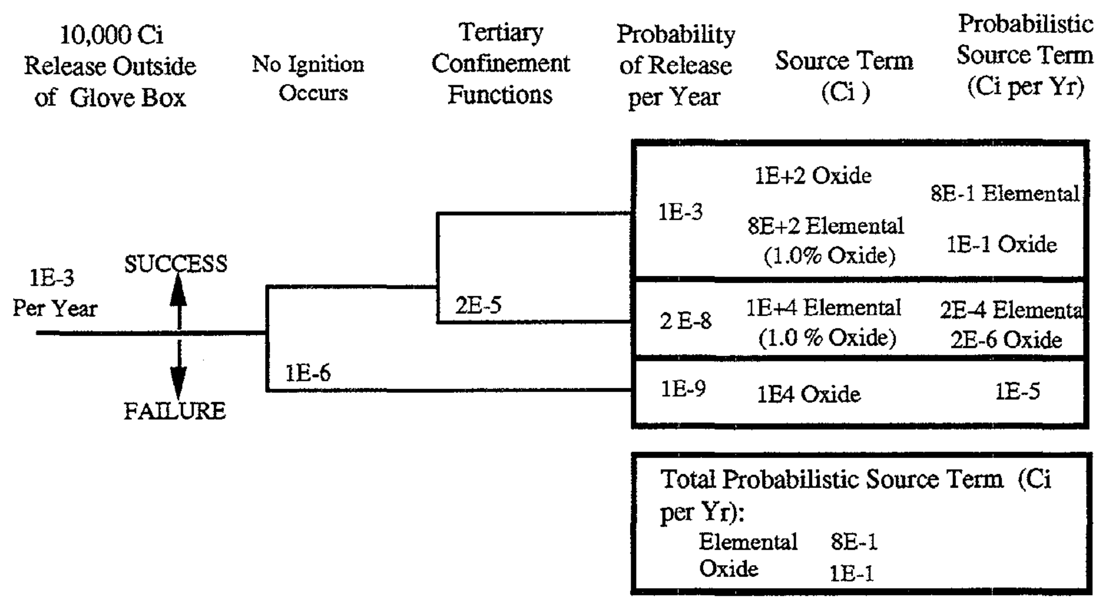

Figure 4.3 Operating Basis Accident at Mound

The event tree in Figure 4.3 describes the OBA for T-Building, including the effects of tertiary confinement. The first end state in this event tree is estimated by the team to have a probability of occurrence of 1E-3 per year. For a 10,000-curie release, 800 curies would leak out directly to the environment with 1% (8 curies) being converted to oxide nearby. The remaining 9,200 curies would enter the ECS and 1% (92 curies) would be released out of ECS as oxide. Thus, the source term would be 100 curies of tritium oxide and approximately 800 curies of elemental tritium. For a probability of occurrence of 1E-3 per year, the probabilistic source term from this occurrence would be 0.8 curies per year of elemental tritium and 0.1 curies per year of tritium oxide.

The second end state has a probability of occurrence of 2E-8 per year. In this sequence, the tertiary confinement fails, and the 10,000 curie release is exhausted to the environment through the stack. The probability of not having tertiary confinement is 2E-5. This is verified by operating experience where the ECS was not operable and was unable to accomplish its confinement function (1 hour in 7 years of operating history). The probabilistic source term would be 2E-4 curies per year of elemental tritium, of which 1% converts to oxide nearby.

The third end state has a probability of occurrence of 1E-9 per year. This sequence is the case of a fire coincident with the OBA. Again, the probability of ignition chosen in Figure 4.3 is consistent with the FSARs for Mound. In this sequence, the ECS is automatically bypassed, and the source term would be 10,000 curies of tritium oxide. The probabilistic source term would be about 1E-5 curie of tritium oxide per year.

The total probabilistic source term for an OBA in T-Building, accounting for the effects of tertiary confinement, is 0.8 curies of elemental tritium and 0.1 curies of tritium oxide per year.

Individual Exposures from Operating Basis Accidents

For identical weather conditions, the maximum individual exposure for a given source term of tritium depends on the release height and whether the tritium is in the elemental or the oxide form. The stack at RTF has a height of 50 feet, and the stack at Mound has a height of 200 feet. The highest hazard from exposure to tritium is primarily from the oxide form, as discussed earlier. The release of tritium oxide at SRS is estimated to be 5 times higher than at Mound for an OBA due to design and operational differences between the two facilities.

Table 4.3 compares the exposures to the maximum individual in the public near SRS and Mound for the operating basis accidents. The distances are listed from the site boundary. At Mound, the higher stack results in the plume touching the ground at around 1 mile beyond the site boundary, and the center of the plume touching the ground at around 3 miles. This accounts for the exposure shown for Mound in Table 4.3 being higher at the 5 mile point as compared to the exposure at 1 mile.

The calculated exposures to individuals are based upon an assumed 4-hour release. In actuality, the release could take days or weeks, there could be ample time to leave the site boundary, and there could be more conversion to oxide than the 1% assumed for a 4-hour release.

Distance from Site Boundary	SRS (rem per year)	Mound (rem per year)
0 meters (0 mile)	3.0E-7	0
1,613 meters (1 mile)	2.8E-7	5.0E-9
8,000 meters (5 miles)	1.7E-7	3.9E-8
16,129 meters (10 miles)	1.1E-7	2.4E-8
80,000 meter (50 miles)	3.0E-8	5.4E-9

Table 4.3 Probability of Maximum Individual Exposure (rem/year) to the Public for Operating Basis Accidents

Population Exposures from Operating Basis Accident

For a given radiological source term, differences in population exposures of the general public near the facility depend on the height of the release, distance to the site boundary, and the size of the exposed population. The stack at Mound is higher than at SRS. At SRS, the tritium facility is located near the center of the site. The nearest site boundary is 7.2 miles away. Mound has a small site that is located within the city limit of Miamisburg. The nearest site boundary is less than 0.25 miles from the tritium facility. The total population within 10-miles of the SRS site boundary is around 65,000. The population within 10 miles of the Mound site boundary is 323,000. The population within 50-miles is 740,000 at SRS and 3,035,000 at Mound.

As shown earlier, the source term for an operating basis accident is higher at SRS. The elevated release from the taller stack at Mound causes the plume to travel further out before touching the ground. SRS has an advantage of greater distance to the site boundary. The lower population density within 10-miles of the SRS site contributes to reducing the population exposure.

When all of these factors are taken into account, these population exposures are nearly equal between the two sites. The differences in population exposure are well within the uncertainty of the calculations. The results are presented in Table 4.4.

	SRS (person-rem/year)	Mound (person-rem/year)
10 Miles of Site Boundary	6.8E-4	7.8E-4
50 Miles of Site Boundary	2.7E-3	2.0E-3

Table 4.4 Probability of Population Exposure to the Public (person-rem/year) for Operating Basis Accident

4.4 Accidents Beyond the Design Basis

Source Term Estimates for Accidents Slightly Beyond the Design Basis

Internal events, external events, and extreme natural phenomena were considered in the evaluation of beyond design basis events. A large earthquake was chosen as the beyond design basis event for discussion. At both SRS and Mound, tritium is located in multitude of tanks and reservoirs. These, in-turn, are located in different glove boxes that are located in different rooms. At SRS, tritium processing and storage will be in two different buildings. Internal events such as fire or explosion would be localized and could only impact a fraction of the total tritium inventory. These facilities are equipped with sprinkler systems and contain very little flammable material to spread a fire. Severe external events, such as plane crash or explosion at nearby locations, have extremely low frequency and would only impact some of the tritium. Natural phenomena, such as damaging floods, are extremely unlikely, and high winds have much lower frequency than earthquakes and would only indirectly affect underground facilities such as RTF and T-Building.

An earthquake of about 0.2g is slightly beyond the design basis for moderate hazard facilities at both Mound and SRS. T-Building and RTF have been shown in their respective FSARs to be able to survive a 0.2g earthquake. However, at SRS, structures in Building 234H, where tritium reservoirs could be stored would fail under a 0.2g earthquake, according to WSRC. Most of the WR reservoirs in 234H are stored in protective cabinets. In the event of a 0.2g earthquake, some WR reservoirs that are in 234H would be exposed to falling debris during a 0.2g earthquake which could lead to the release of tritium to the environment.

The reservoirs are judged to be highly impact resistant, the weakest part being the reservoir stem. Based on information in the 200-Area SAR, the stem and reservoir are ductile, and only 0.1% of WR Reservoirs whose stems are bent are expected to fail. Only the reservoirs outside of the cabinets would be subject to such bending.

One consideration in estimating the likelihood of failure of WR reservoirs is evidence in the literature that stainless steel exposed to tritium under pressure for long periods of time decreases in fracture toughness by many fold. The study presented here does not account for the fact that reservoirs deteriorate when exposed to tritium. Because of conservatism in design, it has been assumed here that WR reservoirs within their design lives are sturdy and that no WR reservoirs will be allowed to remain in storage beyond their design lives.

If there is a failure of a reservoir following gross failure of structures in 234H during an earthquake, elemental tritium would be released, and it is estimated that 1.0% of the tritium would be converted to oxide near the plant. The release would be at ground level, directly to the environment, with very little chance for build up of a flammable mixture. The probability that a fire would occur and convert all of the released tritium to oxide is estimated to be 1E-2 per earthquake event. The event tree analysis in Figure 4.4 estimates the probabilistic source term associated with the gross failure of structures in 234H during a 0.2g earthquake.

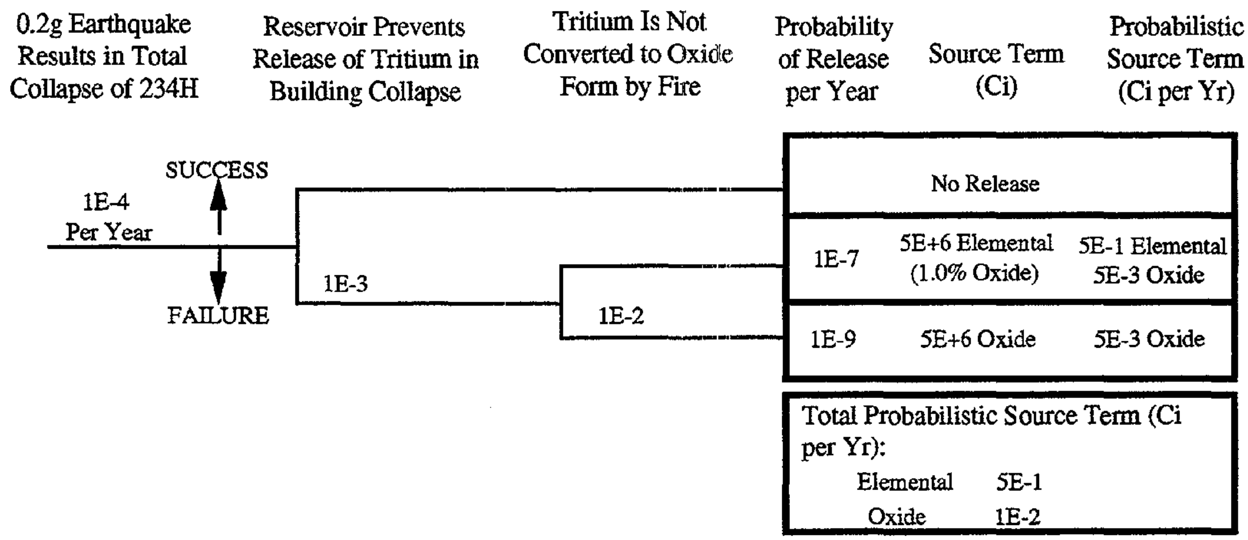

Figure 4.4 Tritium Release Due to Earthquake of 0.2 g for Reservoir Storage, Finishing and Packaging in Building 234H

For the first end state, no release is expected. The probability of release for the second end state is 1E-7 per year, and 5E+6 curies of elemental tritium is released. The probabilistic source term would be 0.5 curies per year of elemental tritium of which 1% is converted to oxide (5E-3 curies per year).

The probability of release for the third end state is 1E-9 per year. In this sequence a fire occurs and the source term is 5E+6 curies of tritium oxide. The probabilistic source term for this sequence is 5E-3 curies of oxide per year. The total probabilistic source term for this event is 0.5 curies of elemental tritium and 0.01 curies of tritium oxide per year.

Exposures for Accidents Slightly Beyond Design Basis

The probability weighted maximum individual exposure for a 0.2g earthquake at SRS owing to the failure of structures in Building 234H is 6.3E-9 rem per year. The total population exposure for this event is given in Table 4.5.

	SRS (person-rem/year)
10 Miles of Site Boundary	1.4E-5
50 Miles of Site Boundary	5.5E-5

Table 4.5 Probability of Population Exposure (person-rem/year) from 0.2g Earthquake

<u>Source Term Estimates for Events Significantly Beyond the Design Basis</u>

An extremely severe earthquake, well in excess of 0.2g, could cause the gross failure of structures, systems and components in either RTF or T-Building. Such an event would have an extremely low probability of occurrence. To evaluate the full spectrum of events and their consequences, an earthquake of sufficient magnitude to cause gross failures of structures, systems and components in T-Building or RTF was evaluated. Such an event would have a probability of less than 1E-6 per year. An extremely severe earthquake at either SRS or Mound would impact the entire tritium inventory in process, and a significant uncontrolled release of tritium would occur.

Differences between T-Building and RTF in the size of components in process lines could make a difference in the potential hazards arising from a severe accident event. At Mound the largest components are on the order of 200 liters, while at SRS the largest components in the processing operations are on the order of 1,500 liters. As a result, Mound typically would have only about 5% of the consolidated tritium inventory tied up in reservoir loading and unloading, while SRS would have about 9% (compare Tables 3.1 and 3.2). RTF uses larger components and has higher capacity because it was designed some years ago for a larger throughput of reservoirs than has been specified for the components that would be added at Mound to meet future throughput demands. If a small, constant annual throughput is assumed for both facilities, then the larger size of tanks is a disadvantage to RTF because a certain minimum amount of tritium is required to make the process work under its design assumptions.

The in-process inventory is more vulnerable to gross failure of structures, systems and components than the inventory in storage. Thus, the team has assumed that the source term would be proportional to the amount of material in process (purification, loading and unloading, see Tables 3.1 and 3.2). The ratio of material in process at T-Building to the amount at RTF is 6/12.

For the extremely severe earthquake it is assumed that 4E+7 curies of elemental tritium is released at SRS and 2E+7 is released at Mound, with the difference being proportional to the difference in the amount of tritium in process at the two facilities. For a frequency of less than 1E-6 per year, the total probabilistic source term would be 20 curies per year at Mound and 40 curies per year at SRS.

In the event of an extremely severe earthquake, the stacks at both sites would fail, and the tertiary confinement in T-Building would fail. The release is assumed to be elemental tritium for this accident. The release would be at ground level and the tritium would seep slowly out of the structure and upward through the ground. This scenario is representative of other low probability events which might result in a ground level release.

Exposures for Events Significantly Beyond the Design Basis.

The maximum exposed member of the public for a ground level release typical of gross failure of structures, systems an components would be the person closest to the point of release. At SRS, the site boundary is 7 miles from the tritium facility, and the maximum exposed individual would receive an estimated exposure of 0.25 rem in the event of such a low probability accident. At Mound the nearest site boundary is less than 0.25 miles away, and the maximum exposed member of the public would receive an estimated exposure of 31 rem in the event of such a low probability accident.

These estimated exposures are used to compare to the DOE Safety goal for an individual at the site boundaries.

The total population exposures depend on the quantity of tritium released, the distance to the site boundary, and the population. Table 4.6 summarizes the analysis results.

	SRS (person-rem/year)	Mound (person-rem/year)
10 Miles of Site Boundary	5.6E-4	4.3E-3
50 Miles of Site Boundary	2.2E-3	5.6E-3

Table 4.6 Probability of Population Exposure from an Extremely Severe Earthquake

5.0 Comparison of Mound and SRS Risks to DOE Safety Goals

This section describes the approach taken for comparison of the risk associated with consolidated tritium operations at Mound and SRS to the DOE quantitative Safety Goals. The approach provides a means of converting the goals in SEN 35-91 into radiation exposures and associated probabilities for the maximum exposed individuals and the population within 10 miles of the two sites. Using this approach, the team compared the probabilities and radiation exposures associated with the goal statements to the probabilities and radiation exposures described in this report for various types of accidents and normal operations.

5.1 Goal for Average Individual

The first DOE safety goal applies to an average individual located near a nuclear facility and is stated as follows:

> The risk to the average individual in the vicinity of a DOE nuclear facility for prompt fatalities that might result from accidents should not exceed one-tenth of one percent (0.1%) of the sum of prompt fatalities resulting from other accidents to which members of the population are generally exposed. For evaluation purposes, individuals are assumed to be located within 1 mile of the site boundary.

The probability of an early fatality from an acute radiation exposure can be converted into the probability of receiving sufficient radiation exposure to cause that early fatality. Acute fatality is a threshold effect; i.e., below a threshold of 200 rem of whole body exposure, no prompt fatalities have ever been observed (NUREG-1150). The risk of prompt fatality begins to rise after exposure exceeds the threshold value of 200 rem.

The distance to the nearest site boundary at Mound is 0.2 miles, and at SRS the site boundary is about 7 miles from the release point.

As was shown in Section 4.4, even for a significantly beyond design basis event, the maximum exposure for an offsite individual would be 0.25 rem at SRS and 31 rem at Mound.

Thus, the maximum individual exposures within one-mile of the site boundary are well below 200 rem. Therefore, the risk of prompt fatality is small at both sites, and both meet the first safety goal.

5.2 Goal for Population Exposure From Operational Release

The second DOE safety goal applies to populations and is stated as follows:

> The risk to the population in the area of a DOE nuclear facility for cancer fatalities that might result from operations should not exceed one-tenth of one percent (0.1%) of the sum of all cancer fatality risks resulting from all other causes. For evaluation purposes, individuals are assumed to be located within 10 miles of the site boundary.

A conversion of this second safety goal into the probability of cancer death per person per year can be made as follows:

> The risk that an average individual will die from cancer ("...resulting from all other causes...") is approximately 2E-3/yr.

To assess whether the facilities meet the SEN-35-91 safety goal for operational release, the team evaluated the 50-year maximum exposure rate from normal operational releases of 2,000 curies per year as was discussed in Section 4.2. Based on BEIR V, an exposure of 1,250 person-rem yields 1 cancer on the average. The population exposure rates for Mound and SRS and the associated cancer risk are shown in the following table.

		Risk Goal		Calculated Risk	
	General Population Within 10-miles of Site Boundary	Expected Number of Cancers From All Causes (Fatalities Per Year)	0.1% of Expected Cancers (Fatalities Per Year)	Population Exposure (Person-rem Per Year) For Normal Operation	Cancer Risk From Tritium Operation (Fatalities Per Year)
SRS	6.5E+4	1.3E+2	**1.3E-1**	2.2E+1	**1.8E-2**
Mound	4.0E+5	8.0E+2	**8.0E-1**	1.6E+2	**1.3E-1**

Table 5.1 Comparison of the Safety Goal to Calculated Fatalities for Normal Operational Releases of 2,000 Curies per Year.

Based on this calculation of population risk for operational releases, both Mound and SRS will meet the safety goal. The assumptions used in this calculation are conservative. The cancer risk from operational releases is likely to be lower than what is calculated here.

6.0 Summary and Conclusions

6.1 Summary

Table 6.1 summarizes the probabilistic source term for the elemental and oxide forms of tritium for the five categories of releases addressed in Section 4. The event tree analysis demonstrated that the transportation release per shipment was very small. Also, for the small number of shipments required to consolidate at Mound, the total probabilistic source term would be insignificant. The most significant source term occurs as a part of normal operations. Such source terms can have a broad range, so bounding estimates of 50 and 2,000 Curies/year were developed based upon M&O contractor estimates for future operation. Table 6.1 only presents the results of the higher estimate of 2,000 Curies/year.

	SRS		Mound	
	Elemental Tritium	Tritium Oxide	Elemental Tritium	Tritium Oxide
Transportation	-	-	2.5E-4 Ci per shipment	2.5E-4 Ci per shipment
Normal operations	6.0E+2 Ci/year	1.4E+3 Ci/year	6.0E+2 Ci/year	1.4E+3 Ci/year
OBA within the design basis	5.0E+1 Ci/year	5.0E-1 Ci/year	8.0E-1 Ci/year	1.0E-1 Ci/year
Beyond design basis earthquake (0.2 g)	5.0E-1 Ci/year	1.0E-2 Ci/year	0	0
Extremely severe earthquake	4.0E+1 Ci/year	4E-1 Ci/year	2.0E+1 Ci/year	2.0E-1 Ci/year

Table 6.1 Summary of Mound and SRS Probabilistic Source Term

The results of these estimates of total probabilistic source term are used to evaluate the consequences to maximum exposed individuals and the populations surrounding the two sites. Table 6.2 summarizes the consequences in terms of the maximum exposed individuals for the probabilistic source terms in Table 6.1. As discussed, the transportation accident was not evaluated on a total risk basis because the probabilistic source term from such an event, when taking into account the total number of shipments was so much lower as to not warrant further consideration.

The results presented are for individuals near the site boundary or where ever the maximum exposure occurs. For instance, for the source term related to normal operation, the exposure would be highest where the plume touches the ground from the stack release. For a ground release such as would occur in the event of gross failures of structures systems and components as a result of an extremely severe earthquake, the maximum exposed individual would be at the site boundary.

	SRS rems/yr	Mound rems/yr
Normal operations	9.5E-3	8.7E-3
OBA within design basis	3.0E-7	4.3E-8
Beyond design basis earthquake (0.2 g)	6.3E-9	–
Extremely severe earthquake	2.5E-7	3.1E-5

Table 6.2 Summary Comparison of Maximum Individual Exposures to the Public for Mound and SRS

Table 6.3 summarizes the population exposures resulting from the probabilistic source terms stated Table 6.1 for the population near the sites for four of the five categories of releases evaluated in Section 4. The transportation accident was not evaluated for the reason discussed above. The population exposures are dominated by the source terms associated with normal operations. For normal operations tritium release, the difference in exposure to the general public near the facility depends on the height of the release, distance to the site boundary, and the size of the exposed population. Because of higher population density and a smaller site, Mound has a higher population exposure by a factor of seven within 10 miles of the site boundary owing to normal operations than does SRS.

For the bounding accident of gross failure of structures, systems and components, the longer distance to the SRS site boundary compensates for the higher release, and the lower population density results in lower population exposure. The population exposure at Mound is about a factor of eight higher for the population within 10-miles of the site boundary, and about a factor of three higher for the population within 50 miles.

	SRS		Mound	
	10 mile (person rem/year)	50 miles (person rem/year)	10 mile (person rem/year)	50 miles (person rem/year)
Normal operations	2.2E+1	8.7E+1	1.6E+2	4.0E+2
OBA within design basis	6.8E-4	2.7E-3	7.8E-4	2.0E-3
Beyond design basis earthquake (0.2g)	1.4E-5	5.5E-5	–	–
Extremely severe earthquake	5.6E-4	2.2E-3	4.3E-3	5.6E-3

Table 6.3 Summary Comparison of Population Exposures to the Public for Mound and SRS

6.2 Overall Conclusion

T-Building is a moderate hazard facility. The releases from normal operations present the largest probabilistic source term and dominate the public risk associated with operations. The Operating Basis Accident and extremely severe earthquake account for similar probabilities of public exposures for the accidents analyzed at SRS. The extremely severe earthquake accounts for the highest probability of public exposures for the accidents analyzed at Mound. Even such a severe accident and its attendant probabilities of exposure are small in comparison to background radiation exposure at both sites.

RTF is a moderate hazard facility. Tritium operations that would remain in 232H and 234H also present low risk. Storage of reservoirs in 234H presents a higher risk for the SRS consolidation plan than the Mound consolidation plan. The releases from normal operations present the dominant risk for tritium consolidation at SRS. Releases from OBA within the design basis account for the highest probability of population exposure of the accidents analyzed for SRS. However, the risk to the public from an OBA near Savannah River is very small.

For projected normal operational releases, SRS has an advantage over Mound in terms of population exposure, primarily because SRS is a large site, located away from a densely populated areas. The population exposures from normal operations at both sites are, however, over a thousand times lower than the population exposures from background radiation.

Considering the relative strengths and weaknesses discussed above, consolidation at either Mound or SRS would result in a comparably low probabilities of exposures as a result of accidents. However, for a large release caused by events with probability of occurrence of less than E-6 per year, such as an extremely severe earthquake, SRS has an advantage, primarily because SRS is a large site, located away from densely populated areas.

6.3 Conclusion of Comparison of Mound and SRS Risks to DOE Safety Goals

At both facilities, the maximum individual exposures within one-mile of the site boundary are well below 200 rem, even for an extreme accident. Also, the probability of such accidents is very low, and it is unlikely that there is any accident that will cause an acute exposure exceeding 200 rem offsite. Therefore the risk of prompt fatality is diminishingly small at both sites, and both meet the first safety goal.

The increase in risk of cancer fatalities for the population within 10-miles of each facility resulting from normal operational releases is below 0.1 percent of the cancer fatality risk from all other causes. Therefore, both sites also meet the second safety goal.

7.0 Reference Documents

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2. "Mound Laboratory - External Events Analysis," PLG-0728, September 1989.

3. "Fault Tree Analysis of The Emergency Containment System," EGG-EA-6549, March 1984.

4. "Safety Evaluation of The Effluent Removal System," PLG-0508, September 1986.

5. ORDER, DOE 6430.1A, General Design Criteria, April 4, 1989.

6. ORDER, DOE 5480.11, Radiation Protection for Occupational Workers, December 21,1988.

7. ORDER DOE 5400.5, Radiation Protection of the Public and the Environment, February 8 1990.

8. "Design and Evaluation Guidelines for Department of Energy Facilities Subjected to Natural Phenomena Hazards," UCRL-15910, June 1990.

9. "Final Safety Analysis Report for the SW/R Tritium Complex," MLM-ML-92-42-0001, February 4, 1992.

10. "Mound Facility Risk Review," JBFA-147-91, Vol. 1, October 1991.

11. "Mound Tritium Feasibility Study," EG&G Mound Applied Technologies, Vol. 1, August 1992.

12. "DP Safety Survey Report, Seismic Assessment of Savannah River Facilities: Tritium Facilities, 232-H/234/H/238-H," SAIC-91/1238, September 1992.

13. "DP Safety Survey Report, Tritium Facilities (Buildings 232-H, 234-H, and 238-H)", Draft SAIC report, December 1991.

14. "Structural Evaluation of Mound Laboratory Buildings Under Tornado and Earthquake Conditions," Corporate Engineering Department Report No. 165, July 1974.

15. "Final Safety Analysis Report, Replacement Tritium Facility," WSRC-1-1-vol-10, Rev.1, 1990. (Classified)

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17. U.S, Nuclear Regulatory Commission Regulatory Guide 1.111, "Methods For Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases From Light-Water -Cooled Reactors," Rev.1, 1977

18. A.R. York, et al., "Design of a Small Type B Package for the Shipment of Radioactive Gas," PATRAM 1992,

19. "Report of the Task Group on Operation of Department of Energy Tritium Facilities," DOE/EH-0198P, October 1991.

20. "Nonreactor Nuclear Facilities: Standards and Criteria Guide," DOE/TIC-11603-Rev.1, September 1986.

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22. DOE, "Air Transportation Safety Analysis Report," expected 1992.

23. "Tritium Air Shipment Miles Between Department of Energy Plants," Garrison October 6, 1992.

24. "Health Effects of Exposures to Low Levels of Ionizing Radiation," BEIR V Report, National Research Council, 1990.

25. "Safety Analysis - 200 Area, Savannah River Plant Tritium Processing Facilities," DPSTSAWD-200-21, September 1987, pg. 5.77. (Classified)

26. "Fusion Technology, G.R. Caskey, 8(1985), pg. 2293.

27. "MELCOR Accident Consequence Code System (MACCS)," Vol. 2, Model Description, NUREG/CR-4691, Sandia National Laboratories.

28. DOE Standard-1013-92, "Guidance on Preliminary Hazard Classification and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Reports," July 1992.

29. "Replacement Tritium Facility," White Paper, WSRC-RP-92-1037, presented to DNFSB, September 1, 1992.

30. "Tritium Control," P. Lamberger and M. Rogers, MLMl-332, January 28, 1986.

31. "DP Safety Survey Report, Replacement Tritium Facilities (Building 233-H)," Draft SAIC report July 1992.

APPENDIX A - RADIATION EXPOSURE CALCULATIONS

This Appendix presents the assumptions and methods used in calculating maximum individual exposures and population exposures for hypothetical releases of tritium oxide and elemental tritium for various stack heights.

A.1 Assumptions and Methods for Calculating Maximum Individual Exposures

The maximum individual exposure (whole body) stemming from the postulated release of tritium in oxide or elemental form was calculated using the following assumptions:

1. Meteorology - Class F, 1 m/sec wind speed (NRC Regulatory Guide 1.3 or 1.4), no change in meteorological conditions during 50-mile plume transit.

2. Release - Over 2 hours.

3. Plume - no decay and no deposition during transit. (Note: No account was taken of the possible conversion by microorganisms (relatively quickly, ~ 10 min.) of deposited elemental tritium on soil and re-emission as tritium oxide. Reference - "A Simple Model to Calculate Doses for Acute Tritium Releases Based on HT Field Experiments in Canada and France", Pg 544-549, Fusion Technology, Vol. 21, March 1992.)

4. Release heights - ground level, 15 meter (typical of RTF stack at SRS), and 60 meter (typical of T-Building stack at Mound).

5. Location of individual - outside (non-sheltered) on center-line of plume on flat terrain.

6. Plume model - Simple Guassian plume equation used to determine downwind ground-level concentration at plume center-line (NUREG/CR-3332, Chapter 14).

7. Biological parameters -

   - 2 hour exposure via inhalation of 2.4 cubic meters based on ICRP Reference Man (ICRP 23), for an adult male breathing rate of 9.6 cubic meters per 8 hours.

   - Dose conversion factors in rem/micro Ci is of 6.3E-5 for tritium oxide and 4.4E-9 for elemental tritium (DOE/EH-0071, pg. 2.5)

   - Increased exposure from tritium oxide by factor of 1.5 to account for absorption of tritium oxide through the skin.

To validate the approach used in SCIENTECH's calculations, the M&O contractors were asked to perform maximum individual exposure calculations for a hypothetical 10,000 curie release for distances of 0.5, 1, and 5 miles for both sites. Both elemental tritium and tritium oxide releases were evaluated. Each M&O Contractor was asked to use the same approach as was used in its safety analysis report. The following tables show the results for two release heights as calculated. The calculated exposures in Table A-1 are within one order of magnitude for the 15 meter release height.. In Table A-2, the calculated exposures do not agree well for distances less than that where the plume center reaches the ground (about 4 miles) However, for distances beyond the point where the plume center reaches the ground, the results show good agreement. Since calculation of maximum individual exposures are only performed where the plume center reaches the ground, this variation due to the models does not affect the validity of the results.

	0.5 Miles (rem)		1 Mile (rem)		5 Miles (rem)	
Calculated By:	T2	HTO	T2	HTO	T2	HTO
SRS	2.32E-6	8.7E-2	1.07E-6	4E-2	1.17E-7	4.4E-3
Mound	2.15E-6	5.5E-2	1.31E-6	3.4E-2	2.02E-7	5.2E-3
SCIENTECH	6.5E-6	1.4E-1	3.5E-6	7.5E-2	4.7E-7	1.0E-2

Table A.1 Maximum Individual Exposure For 10,000 Curie Release from a 15-Meter Release Height

	0.5 Miles (rem)		1 Mile (mem)		5 Miles (rem)	
Calculated By:	T2	HTO	T2	HTO	T2	HTO
SRS	1.55E-7	5.8E-3	1.68E-7	6.3E-3	6.4E-8	2.4E-3
Mound	1.6E-13	4.12E-9	3.81E-9	1E-4	5.89E-8	1.5E-3
SCIENTECH	0	0	2.3E-8	5.0E-4	1.8E-7	3.9E-3

Table A.2 Maximum Individual Exposure For 10,000 Curie Release from a 60-Meter Release Height

A.2 Assumptions and Methods for Calculating Population Exposures

The population exposures are calculated in the same manner as the maximum individual exposure, described above.. In addition, the following simplifying assumptions were made for the population exposure calculations:

1. Off-site populations within 0 to 10 miles, and 0 to 50 miles from the site are assumed to be exposed to the release plume for the duration of release.

2. Populations were determined from site data and assumed to be uniformly distributed in each of the annuli.

3. The annuli around each site was divided into 16 sectors, and populations were divided equally into each of the sectors for the 2 distances. This assumption puts the plume in just one sector as it travels outward in a straight line (simple Guassian plume model). With this model the plume could travel in any sector and affect the same number and distribution of people. Thus, this simplified approach does not account for the location of population centers relative to the annual distribution of wind direction and stability class.

4. Mid-point distances were used, assuming that the entire sector population for the range was at the mid-point of each of the annuli.

5. The population exposure was calculated for a 2 hour duration of plume passage for inhalation pathway for both forms of tritium (plus skin absorption for tritium oxide)

Tritium facilities at the Savannah River Site are in the 200 Area of the H-Area which is near the center of the site. The nearest site boundary from the RTF stack is 7.3 miles in the north west direction. Key population centers that are included in a 50-mile radial zone are Augusta, Georgia; North Augusta, South Carolina; Orangeburg, South Carolina.; and Aiken, South Carolina.

Mound is located within the metropolitan area of Miamisburg, Ohio. The nearest site boundary from the T-Building Stack is 300 meters (0.2 miles) away. Key population centers that are included in a 50-mile radial zone are Cincinnati and Dayton, Ohio.

The populations within the 2 concentric annuli used in the population exposure calculations are shown in Table A-3.

Radial Distance From Site Boundary	RTF at SRS	T-Building at Mound
0-10 miles	65,000	323,000
0-50 miles	740,000	3,034,000

Table A.3 Comparison of Populations within 10 and 50 Miles of Each Site

The population exposure calculations are not subject to the same modeling errors as for maximum individual exposures so no validation of the approach was necessary by the M&O contractors.

APPENDIX B - ACCIDENTS CONSIDERED IN THIS REPORT

In an effort to compare the risk differences between Savannah River Site and Mound, accidents were considered that are typical of a tritium facility safety analysis. A list of these accidents, shown below, is recommended in Appendix J of "Nonreactor Nuclear Facilities: Standards and Criteria Guide."

B.1 Release of Radioactive Material to the Environment Outside of Buildings

The following types of tritium releases that could occur outside of buildings were considered:

1. Tritium container-handling accident.

Tritium reservoirs are located outside of buildings during transport between adjacent buildings at each facility, and when reservoirs are shipped off site. At Mound, some handling will occur when reservoirs are moved between the T-Building and the SW Building, and at SRS similar handling will occur when reservoirs are moved between RTF and Buildings 232H and 234H. Such movement occur only occasionally, and over very short distances in a highly restricted area. The team did not consider this to be a significant source of risk and did not analyze this further.

When tritium reservoirs are shipped off site during consolidation, they will be packed in DOT qualified Type B steel drums. In the consolidation of the tritium activities, some existing inventories of tritium would have to be moved. The associated risk is analyzed in Section 4.

2. On-site transportation accident.

There has never been an on-site transportation accident that resulted in the release of tritium at either facility. Mound's estimate of the frequency of any major on-site transportation accident is 10^{-6} per year, and the frequency of an on-site transportation accident releasing tritium is less than 10^{-6} per year. The Savannah River Site is much larger than Mound. So the distance traveled on site would be greater and risk would be higher. Based on the very low frequency for such events, this was not considered a significant hazard and was not evaluated further.

B.2. Release of Radioactive Material to the Environment Inside of Buildings

The following in-facility accidents were considered during facility walkdowns at Mound and SRS:

1. Tritium release during handling.

2. Tritium release to building which is all oxidized and concurrent failure of tritium cleanup system.

3. Tritium container accident (e.g., leaks from reservoir valves, sheared reservoir valves, reservoir explosion).

4. Internal missiles rupturing tritium containing boundaries.

5. Hydrogen explosion resulting in tritium leakage.

6. Tritium system over-pressurization (e.g., rapid heating of uranium storage beds).

7. Loss of power to confinement ventilation system.

8. Failure of glove box purification system.

9. Simultaneous primary and secondary confinement failures due to human error.

10. Other tritium releases inside buildings.

The complexity of the systems and processes at each site made it impractical to analyze each of these accidents in great detail. The only reasonable way to compare the relative risk for the above inside-building accidents was to make some assumptions about the relative difference at the two sites. Based on the team's review of facility reports and inspection of the processing equipment, it was concluded that the difference between the two facilities for these accidents, after consolidation, would be less than one order of magnitude. This is discussed in detail in Section 4 with regard to operating basis accidents.

B.3 Release of Nonradioactive Hazardous Materials

- Hydrogen release.
- Liquid releases (acids, chemicals).
- Fires and Explosives

Based on review of the facility SARs and walkdowns, it was found that neither facility contained significant quantities of nonradioactive hazardous material. Since the quantities present did not represent an off-site hazard, they were not analyzed further.

B.4 Fires and Explosions

- Fires involving ordinary combustible materials (Class A).
- Fires involving flammable or combustible liquids, flammable gases, greases, and similar materials (Class B).
- Fires involving energized electrical equipment (Class C).
- Fires involving certain combustible metals (Class D).
- Hydrogen explosions.

The existing safety studies at both facilities agree that the anticipated frequency of tritium release resulting from facility fires or explosions is on the order of 10^{-6} per year. Based on walkdowns of the facilities, the team did not find reason to disagree with that judgment. This frequency was used in event tree analysis in Section 4.

B.5 Severe Natural Phenomena

1. Earthquake

The design basis accidents for natural phenomena at DOE sites are defined in UCRL-15910. The magnitude of these design basis accidents depends on the site and the hazard classification of the facility. On a given site, each facility can be classified as low, moderate, or high hazard. The classification is based on Table 2-1 in UCRL-15910 and is subject to facility interpretation. At this time, the tritium facility at SRS is considered a high hazard facility, while Mound is considered a moderate hazard facility. Recent DOE guidance appears to indicate that both facilities can be treated as moderate hazard facilities in the future, and the moderate hazard classification for each site was assumed in this report.

The T-Building at Mound has been assessed in its FSAR for a design basis earthquake (DBE) of 0.15 g, and existing seismic analysis indicates that it would withstand a 0.2 g earthquake as well. RTF and building 232H at SRS are both seismically designed for 0.2 g earthquake, while building 234H is claimed in its FSAR to be able to withstand a 0.1 g earthquake. The facility seismic capability only applies to the buildings and not the internal equipment. Although T-Building is seismically qualified, the equipment has not been adequately evaluated. The equipment in RTF has been evaluated, and the large tanks are seismically protected. There is a difference in seismic risk for the storage, finishing and packaging of the reservoirs. These activities are in Building 234H. This is analyzed in Section 4.

The information the team gathered from the M&O contractors on earthquakes is summarized in the following table.

	MODERATE HAZARD (1×10^{-3}/year)*		HIGH HAZARD (2×10^{-4}/year)*	
DOE site	Magnitude	Consequences	Magnitude	Consequences
Mound Plant T-Building	0.15 g	Building survives; Equipment to be designed to survive	0.23 g	Building survives 0.2 g
Savannah River Site RTF**	0.11 g	Building survives, No specific evaluation of equipment	0.19 g	300,000 Ci of <1% oxide released causing 0.08 mrem at site boundary. Building and major components survive
Savannah River Site Building 232H	0.11 g	Building Survives	0.19 g	Building Survives
Savannah River Site Building 234H	0.11 g	Building Survives	0.19 g	Gross Failure of Building Structure

* From UCRL-15910
** From "Replacement Tritium Facility White Paper," WSRC-RP-92-1037, September 1, 1992.

Table B.1 Earthquake Consequences

2. Severe wind and wind-generated missiles.

Based on the facility SARs and the definition of DBAs in UCRL-15910, the buildings at both facilities are expected to survive the design basis wind and tornado.

DOE site	Moderate Hazard Wind (1 x 10^{-3}/yr.)*	Moderate Hazard Tornado (2 x 10^{-5}/yr.)*	High Hazard Wind (1 x 10^{-4}/yr.)*	High Hazard Tornado (2 x 10^{-5}/yr.)*
Mound Laboratory T-Building	137 mph* No Damage**	137 mph* No Damage**	137 mph* No Damage**	137 mph* No Damage
Savannah River Plant** RTF, 232H, 234H	136 mph* No Damage***	136 mph* No Damage***	136 mph* No Damage***	136 mph* No Damage

* From UCRL-15910

** "Structural Evaluation of Mound Laboratory Buildings Under Tornado and Earthquake Conditions," Monsanto Company, CED Report No. 165, July 1974.

*** "FSAR RTF", WSRC-1-1-VOL-10, Rev 1.
"Tritium Processing Facilities," SRP SAR-200 Area, DPSTAWD-200-21, September 1987.

Table B.2 Design Basis Wind/Tornado

3. Flood.

The buildings at both facilities are safe from flood damage. RTF is at an elevation 200-ft higher than the Savannah River. The nearest dam is 30 miles from the SRS, potential dam failures are not expected to affect the SRS. The flood stage at Mound, and assuming multiple dam failures, is 727.5 ft, and the T-Building tunnel is at 830 ft. elevation.

DOE site	Moderate Hazard (1 x 10^{-4}/yr.)	High Hazard (1 x 10^{-5}/yr.)
Mound Laboratory	No Release	No Release
Savannah River Plant	No Release	No Release

Table B.3 Design Basis Flood

B.6 External Man-Made Hazards

1. Missiles, including aircraft crashes.

Hazards resulting from aircraft crashes are considered to be very unlikely (10^{-4} to 10^{-6} per year). There are no airports within 10-miles of the SRS tritium facility. At Mound there are air parks but no large commercial airport within 10-miles; and most future tritium operations will be in the T-Building, which is an underground bomb-proof facility. There have been four airplane crashes on SRS since the 1950s involving DOE/SRS aircraft. One crash occurred in H-Area. WSRC representatives stated to the team that this hazard from SRS aircraft is under administrative control, involves low flying, small aircraft and is not significant hazard to the tritium that would be stored or processed in RTF and 234H. The team concluded that hazards of missiles and aircraft crashes are not credible at either site. The team did not further evaluate this accident scenario.

2. Explosions on nearby transportation routes.

Mound is over two miles from the nearest major interstate highway. An off-site truck accident that significantly impacts the Mound Site has been estimated to be a 10^{-5} per year event. The H-Area at SRS is not accessible by public roads and is greater than two miles from the nearest major route. The team does not feel explosions on nearby transportation routes would lead to tritium release at either facility and did not further explore this accident scenario.

3. Toxic gas release on nearby transportation route or from a neighboring facility.

A rail line is near the Mound site, and the frequency of rail accident is 10^{-5} per year. The site is protected by its elevated location. Any toxic gas release accident near the site may result in partial site evacuation. However, this would not lead to any release of tritium. The 200-Area of SRS is not near any transportation route and does not have any neighboring toxic gas facility. The team did not further evaluated this accident scenario.

4. Accidents at a nearby nuclear facility.

The nearest nuclear facility at Mound would be the other laboratory buildings on the Mound site. The T-Building is an underground bomb-proof facility. T-Building and associated tritium processing equipment would not be affected by any credible (10^{-6} per year) nuclear facility accident at Mound. The tritium facility at SRS is located on an enclosed section of the H-Area. The nearest nuclear facility would be the waste storage area on the South side and the H-Canyon on the East side. On the South side, there is over four hundred feet of separation distance between the waste area fence and the nearest tritium facility building. On the East side there is about five hundred feet of separation distance between the H-Canyon building and the nearest tritium facility building. These distances provide sufficient protection against any credible accidents that may occur in the near by facilities. The team did not feel such accidents could trigger tritium release to the environment and did not evaluate this accident scenario further.